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LCA NETWORKS

Mapping and characterization of LCA networks

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Abstract
Purpose The aims of this study were to provide an up-to-date overview of global, regional and local networks supporting life cycle thinking and to characterize them according to their structure and activities.
Methods Following a tentative life cycle assessment (LCA) network definition, a mapping was performed based on (1) a literature search, (2) a web search and (3) an inquiry to stakeholders distributed via the two largest LCA fora. Networks were characterized based on responses from a survey.
Results and discussion We identified 100 networks, of which 29 fulfilled all six criteria composing our tentative network definition (the remaining fulfilled four to five criteria). The networks are mainly located in Europe and the USA, whilst Africa, the Middle East and Central Asia are less covered regions. The survey results (from 25 network responses) indicate that LCA networks appear to be primarily small- to medium-sized (<100 members) and to include a large proportion of academia and industries, including small- and medium-sized enterprises, with much less involvement of authorities and non-governmental organisations. Their major activities relate to knowledge sharing and communication, support of case studies, and development of life cycle inventories and impact assessment methods. Networks in developing economies have different structures and activities than networks in developed economies and, for instance, more frequently have members from non-governmental organisations. Globally, an increasing trend in the formation of LCA networks over time is observed, which tends to correlate with the number of LCA scientific publications over the same time period. Continental distributions of networks also show a correlation with the number of LCA publications from the same region.
Conclusions The provided list of LCA networks is currently the most comprehensive, publicly available mapping. We believe that the results of this mapping can serve as a basis for deciding where priorities should be set to increase the dissemination and development of LCA worldwide. In this aim, we also advocate the creation of an online, regularly updated database of LCA networks supplemented by an online platform that could facilitate network communication and knowledge sharing.

Keywords Application · Dissemination · Life cycle assessment · Publications · Stakeholder collaboration · Survey · Web search

1 Introduction

Since the 1990s, there has been an increase in the amount of life cycle assessment (LCA) research activities (de Souza and Barbastefano 2011). This increase has been in agreement with phase 1 of the UNEP/SETAC Life Cycle Initiative (2002–2006), which had a focus on methodological development (UNEP/SETAC 2012). In the ongoing phase 2 (2007–2012) of the initiative, there is a stronger emphasis on the dissemination and application of life cycle methodologies and tools. This emphasis is believed to be carried on in the upcoming phase 3. To accommodate this encouragement for dissemination and application, collaboration between LCA researchers is not in itself deemed sufficient, but needs to be supplemented by a wider stakeholder collaboration beyond the sole field of academia. These include businesses, policy makers and NGOs who can link the societal needs to the research efforts and,

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subsequently, the research outcomes to their practical implementations (Camarinha-Matos et al. 2010). More generally, Pavitt (2005) stresses the importance of industrial linkages with universities as a driver for innovation.

We believe that LCA networks can act as platforms for facilitating such multi-stakeholder cooperation. The form of this facilitation may vary since the activities and structures of LCA networks are context-dependent. Networks in developing economies[1] may be mostly preoccupied with issues such as establishing LCA expertise and training capacity at universities and communicating the benefits of the LCA framework to policy makers inexperienced in dealing with environmental issues. An example of this is the African ALCANET (Ramjeawon et al. 2005). In developed economies where LCA is already established and applied to some extent across academia, industry and authorities, the networks may be more focused on knowledge sharing between these stakeholders and the methodological development of LCA. This is the case for the Greek HELCANET and the Italian LCA network (Moussiopoulos and Koroneos 1998; Cappellaro et al. 2008). Finally, in countries where LCA is well established, networks may have a much more narrow focus, e.g. the harmonizing of life cycle inventory (LCI) datasets and databases or the promotion of LCA as a tool within integrated product policy and base their activities and structure on already existing national and international formal or informal networks related to LCA. The German Network on Life Cycle Inventory Data and LCA Center Denmark are examples of this (Bauer et al. 2004; Hauschild and Frydendal 2006).

Assessing the activities and roles of LCA networks is relatively new and coordinated efforts are still needed. At the SETAC Europe 21st Annual Meeting, a special session was given on 'LCA networks: comparison of experience' (Masoni 2011). The presentations at the special session highlighted the similarities and differences between networks, which motivated us to establish an up-to-date overview of (ideally) all existing LCA networks worldwide. This overview aims to be a strong basis for facilitating cooperation and experience sharing between the networks. In Bjørn et al. (2012), we carried out an initial mapping of LCA networks and identified 87 networks (of which not all fully met our definition) located primarily in Europe, the Americas, Southeast Asia and Oceania. Here, these initial mapping results are complemented and refined. We also characterize LCA networks, with a focus on their structure and activities within the LCA framework, and we discuss the potential of LCA networks to facilitate the development of LCA related concepts.

[1] The term developing economy is used in this context to classify countries below the group "high-income economies," thus having a per capita income of less than US $12,476 per year according to the World Bank (2012).

2 Methods

We followed a three-stage methodology composed of (1) defining an LCA network, (2) mapping networks and (3) characterizing networks. These methodological stages did not always follow each other linearly and several iterations between each stage and their activities took place, as indicated in Fig. 1.

2.1 Definition of an LCA network

To our knowledge, there exists no generally agreed upon definition of an LCA network. We therefore propose a definition below and reflect on its appropriateness for future network mapping studies in Section 3.4.5. According to the proposed definition, a network is classified as an LCA network if it meets the six-criterion definition based on Bjørn et al. (2012).

1. Supports a life cycle approach and/or mentions LCA or life cycle thinking in mission/vision/'goal and scope'
2. Includes, as a minimum, members from both the academia and industry (authorities, consultancies, NGOs, etc.,. are allowed, but not required)
3. Is non-profit and hence uses revenues to achieve its goals rather than to distribute them as profit or dividends
4. Is based on some degree of central control and coordination
5. Is an independent entity and not merely a subject-specific subchapter of a larger LCA network
6. Embodies a communication platform to connect all the members (e.g. newsletter, web site, etc.)

An additional restriction has been applied to prevent the inclusion of inactive networks by excluding identified networks, for which most recent activities visible on their web sites (if they have one) are older than 2008.[2] Partly qualifying networks identified by the mapping activities were included as long as they fulfilled at least four of the six criteria and specifically fulfilled criterion 1 (networks were given the benefit of the doubt if it was not possible to check the fulfillment of a criterion). It was decided to include them in the mapping since the LCA network definition is merely tentative and since these networks may contribute to a more complete picture of the activities carried out between different stakeholders in relation to the dissemination, application and scientific development of LCA and its related frameworks. The term 'LCA network' will, in this article, be used interchangeably for fully complying and partly complying networks, unless otherwise stated.

[2] Exceptions are networks that are known to be active from other sources than their web site (e.g. inquiry to stakeholders or survey response).

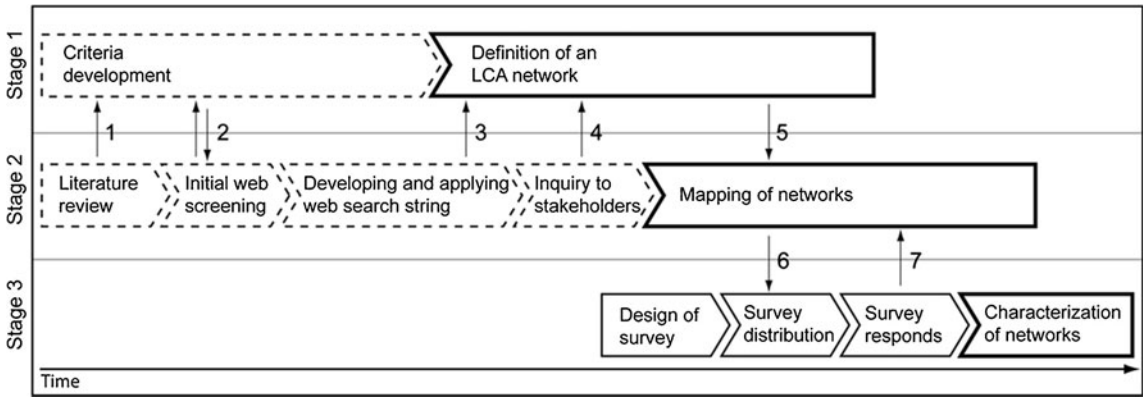

Fig. 1 Activities and results of the three stages in the mapping and characterization methodology. Activities are *chevron/pentagon-shaped*. Activities with *dotted borders* were initiated in Bjørn et al. (2012). Results are highlighted to the *right with bold borders*. The *arrows* represent interactions: *1* Inspiration from previous mappings studies. *2* Iterations. *3+4* Inclusion of partly qualifying networks. *5* Networks to be included in mapping. *6* Networks to receive survey invitation. *7* Networks identified through survey

2.2 Mapping of networks

In Bjørn et al. (2012), we proposed and initiated a systematic mapping process consisting of (1) reviewing the literature, (2) carrying out a web screening, (3) developing and applying a web search string and (4) sending out an inquiry to stakeholders (see Fig. 1). We identified two studies that focused on LCA networks, albeit with narrower scopes than this study, namely Curran and Notten (2006) (identifying LCI-related networks) and Valdivia et al. (2009) (identifying European LCA networks). Following the web screening and development and application of a web search string (details in Bjørn et al. 2012), we posted an inquiry to the subscribers to PRé's LCA Discussion list and members of the 'Life Cycle Assessment' group on LinkedIn (PRé 2012; LinkedIn 2012). Harnessing the two largest LCA fora guaranteed that our inquiry reached a large number of individuals with potential information on LCA networks that were not identified by the previous mapping activities listed in Fig. 1. The inquiry to stakeholders was initiated in Bjørn et al. (2012), but additional responses were included and processed in this study.

2.3 Characterization of networks

We attempted to characterize the identified LCA networks by obtaining information related to (1) geographical coverage, (2) year of foundation, (3) primary language of communication, (4) origin of funding, (5) number of members, (6) involvement of different types of organisations, (7) coverage of LCA-related area(s), (8) form of communication within the network, (9) means of creating awareness of the network and (10) collaboration with other networks. Because the above information could only be obtained on the network web sites to a limited extent, a survey was designed and sent to all identified networks.[3] The purpose of the survey was to characterize existing LCA networks as well as provide an empirical basis for a discussion of their potential roles. Since the network web sites did not always reveal whether or not the networks fulfilled each criterion in the definition, the survey also included yes/no questions checking each criterion.

3 Results and discussion

3.1 List of LCA networks

A total of 100 networks were identified. In addition, eight networks were identified, but discarded because they were deemed inactive due to, e.g. completion of the purpose they were designed for (e.g. hosting a specific conference or carrying out a specific project), closing down due to lack of resources, or reorganization into different network formations. Table 1 presents all 100 identified networks along with some key information for each. A complementary table with additional information can be found in the Electronic supplementary material (ESM).

The last row in Table 1 shows that the mapping activities literature review, internet search and inquiry to stakeholders identified 21, 37 and 42 networks, respectively. It is surprising that the inquiry to stakeholders activity identified more previously unidentified networks than the internet search since the internet search strings went through a large number of iterations and it was thought that not many networks, existing online, had escaped it. This illustrates the difficulty of designing and applying a highly restrictive search string

[3] Exceptions of this were nine networks that were identified after the survey had been distributed (see Fig. 1). These networks were identified by means of survey response to question 12b on 'collaboration with other networks'. These nine networks are marked by a note in Table 1.

Table 1 List of all 100 identified networks along with synthesis of some of their features

Name	Year of formation	Network identified in			Country/Countries	1: Supports a life cycle approach	2: Has members from both academia and industry	3: Is non-profit	4: Has central control and coordination	5: Is an independent entity	6: Embodies a communication platform
		Literature review	Web search	Inquiry to stakeholders							
GLOBAL											
AMEE (Avoidance of Mass Extinctions Engine)	2007			X	The world	Yes	Yes	NA	Yes	Yes	Yes
Ecospecifier[a]	2003			X	The world	Yes	NA	NA	Yes	Yes	Yes
Elusor Environmental Accounting Tools	**2009**		**X**		**The world**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Environment Tools	2012			X	The world	Yes	Yes	NA	Yes	Yes	Yes
Footprinted	2011			X	The world	Yes	Yes	Yes	Yes	No	Yes
IALCEE (International Association for Life-Cycle Civil Engineering)	2006		X		The world	Yes	Yes	NA	Yes	Yes	Yes
ILCA (International Life Cycle Academy)	**2011**			**X**	**The world**	**Yes**	**No**	**Yes**	**Yes**	**Yes**	**Yes**
IEG (International Expert Group on Life Cycle Assessment for Integrated Waste Management)	1998			X	The world	Yes	NA	NA	Yes	Yes	No
ISIE (International Society for Industrial Ecology)	2000			X	The world	Yes	Yes	Yes	Yes	Yes	Yes
PRé LCA Discussion List	1990		X		The world	Yes	Yes	No	Yes	Yes	Yes
LCA links!	**1996**		**X**		**The world**	**Yes**	**No**	**No**	**Yes**	**Yes**	**Yes**
Life Cycle Regional Networks Community	NA		X		The world	Yes	NA	NA	No	No	Yes
Material source	2010			X	The world	Yes	Yes	Yes	Yes	Yes	Yes
Seed4Green	2009			X	The world	Yes	Yes	NA	Yes	NA	Yes
Swiss Discussion Forum on Life Cycle Assessment	1996		X		The world	Yes	Yes	NA	Yes	Yes	Yes
The Evah Institute	**2008**		**X**		**The world**	**Yes**	**Yes**	**No**	**Yes**	**Yes**	**Yes**
The Sustainability Consortium	2009			X	The world	Yes	Yes	NA	Yes	Yes	Yes
UNEP SETAC Life Cycle Initiative	2000		X		The world	Yes	Yes	NA	Yes	No	Yes
EUROPE											
European Platform on Life Cycle Assessment	2005		X		Europe[f]	Yes	Yes	NA	Yes	No	Yes
SPOLD (Society for Promotion of Life-Cycle Assessment Development)[b]	NA		X		Europe[f]	Yes	No	NA	Yes	No	Yes
European Commission–Joint Research Centre, Life cycle thinking and Assessment, Institute for the Environment and Sustainability[c]	2005		X		Europe[f]	Yes	Yes	NA	Yes	No	Yes

Table 1 (continued)

Name	Year of formation	Network identified in			Country/Countries	1: Supports a life cycle approach	2: Has members from both academia and industry	3: Is non-profit	4: Has central control and coordination	5: Is an independent entity	6: Embodies a communication platform
		Literature review	Web search	Inquiry to stakeholders							
IPTS (The Institute for Prospective Technological Studies)[c]	1994			X	Europe[f]	Yes	Yes	NA	Yes	No	Yes
ELCD (The European Reference Life Cycle Data System)[c]	2008			X	Europe[f]	Yes	Yes	NA	Yes	No	Yes
LCA contact site for Central and Eastern European Countries	NA		X		Czech Republic, Estonia, Lithuania, Poland, Slovenia, Hungary	Yes	NA	NA	No	No	Yes
NorLCA (Nordic Life Cycle Association)	**2004**	**X**			**Denmark, Sweden, Norway, Finland, Iceland**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
CREER (Cluster Research, Excellence in Ecodesign & Recycling)	**2007**			**X**	**France, Luxembourg**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
CASE-LCA (Central and Southeast Europe LCA network)	**2011**		**X**		**Serbia, Poland, Hungary, Czech Republic, Slovenia, Croatia, Slovakia**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
GreenWin	2010		X		Belgium	Yes	Yes	Yes	Yes	Yes	Yes
LCA Center	NA	X			Denmark	Yes	Yes	NA	Yes	Yes	Yes
Estonian LCA Network	2011			X	Estonia	Yes	NA	NA	NA	Yes	No
FINLCA (Life Cycle Assessment Framework and Tools for Finnish Companies)	NA		X		Finland	Yes	NA	Yes	Yes	Yes	Yes
avniR (Life Cycle Assessment Platform)	2011		X		France	Yes	No	Yes	Yes	Yes	Yes
EcoInfo	2006		X		France	Yes	Yes	NA	Yes	Yes	Yes
Eco-connexion	**2010**			**X**	**France**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
AGORACV	**2012**			**X**	**France**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
ELSA-LCA (Environmental Life Cycle and Sustainability Assessment)[d]	2008			X	France	Yes	No	NA	Yes	Yes	Yes
German Network on Life Cycle Inventory Data	2002	X			Germany	Yes	Yes	NA	Yes	Yes	Yes
HELCANET (Hellenic Life Cycle Assessment Network/LHTEE)[a]	**1998**			**X**	**Greece**	**Yes**	**No**	**Yes**	**Yes**	**Yes**	**Yes**
ELCAS (Exergy, Life Cycle Assessment and Sustainability)	2009			X	Greece	Yes	Yes	NA	Yes	Yes	Yes
LCA Center Hungary	2008		X		Hungary	Yes	Yes	Yes	Yes	Yes	Yes

Table 1 (continued)

Name	Year of formation	Network identified in			Country/Countries	1: Supports a life cycle approach	2: Has members from both academia and industry	3: Is non-profit	4: Has central control and coordination	5: Is an independent entity	6: Embodies a communication platform
		Literature review	Web search	Inquiry to stakeholders							
Rete Italiana LCA (Italian LCA network)	2006	X			Italy	Yes	Yes	NA	Yes	Yes	Yes
VLCA (Association for LCA in Construction)	1997		X		the Netherlands	Yes	Yes	Yes	Yes	Yes	Yes
Animal Production Systems Group	NA			X	the Netherlands	Yes	No	Yes	Yes	Yes	Yes
IMARES (Institute for Marine Resources and Ecosystem Studies)	NA			X	the Netherlands	Yes	No	Yes	Yes	Yes	Yes
The Environmental Systems Analysis Group	NA			X	the Netherlands	Yes	No	Yes	Yes	Yes	Yes
SmartGreenScans[a]	2011			X	the Netherlands	Yes	No	NA	Yes	Yes	Yes
Ostfold Research Co.	1988			X	Norway	Yes	Yes	Yes	Yes	Yes	Yes
PCLCA (Polish Center for Life Cycle Assessment)	2009		X		Poland	Yes	Yes	Yes	Yes	Yes	Yes
LCA Portugal	**2007**	**X**			**Portugal**	**Yes**	**Yes**	**Yes**	**No**	**NA**	**No**
EcoRussia	**2009**			**X**	**Russia**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Red TemáticaNacional de Análisis de Ciclo de Vida (National Thematic Network on Life Cycle Analysis)	NA	X			Spain	Yes	No	Yes	Yes	Yes	Yes
Spanish LCA society	NA	X			Spain	Yes	NA	NA	NA	NA	No
UNESCO Chair in Life Cycle and Climate Change	2011		X		Spain	Yes	NA	NA	Yes	No	Yes
Catalan LCA Network	**2000**	**X**			**Spain**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Technical University of Cartagena, group conducting LCA studies on photovoltaic devices[a]	**2008**			**X**	**Spain**	**Yes**	**No**	**Yes**	**Yes**	**Yes**	**NA**
CESC (Centre for Sustainable Communications)	2007		X		Sweden	Yes	Yes	NA	Yes	Yes	Yes
CPM (The Swedish life cycle center)	**1996**	**X**			**Sweden**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Miljögiraff[a]	NA			X	Sweden	Yes	No	NA	Yes	Yes	Yes
SIK Food and Climate network	1993			X	Sweden	Yes	No	Yes	Yes	Yes	Yes
Ecoinvent Centre	1997	X			Switzerland	Yes	Yes	Yes	Yes	Yes	Yes
NORTH AMERICA											
ACLCA (the American Center for LCA)	2001	X			US	Yes	Yes	Yes	Yes	Yes	Yes
ASC (Applied Sustainability Center)	NA		X		US	Yes	Yes	NA	Yes	Yes	Yes
CLCA (Center for Life Cycle Analysis)	**2006**		**X**		**US**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

Table 1 (continued)

Name	Year of formation	Network identified in			Country/Countries	1: Supports a life cycle approach	2: Has members from both academia and industry	3: Is non-profit	4: Has central control and coordination	5: Is an independent entity	6: Embodies a communication platform
		Literature review	Web search	Inquiry to stakeholders							
CSS (Center for Sustainable Systems)	1991		X		US	Yes	Yes	NA	Yes	Yes	Yes
EIO-LCA (Economic Input–output Life Cycle Assessment)	1995			X	US	Yes	No	Yes	Yes	NA	Yes
National Photovoltaics Environmental Research Center - Brookhaven National Laboratory[a]	**2004**			**X**	**US**	**Yes**	**Yes**	**No**	**Yes**	**Yes**	**Yes**
Source 44[a]	2012			X	US	Yes	NA	No	Yes	Yes	Yes
CIRAIG (The Interuniversity Research Centre for the Life Cycle of Products, Processes and Services)	2001	X			Canada	Yes	Yes	Yes	Yes	Yes	Yes
LCA Alliance at UBC	2010			X	Canada	Yes	No	NA	Yes	Yes	Yes
Mexican Center for LCA and Sustainable Design	NA	X			Mexico	Yes	NA	NA	Yes	Yes	Yes
REMACIV[a] **(full name unknown)**	**2011**			**X**	**Mexico**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**NA**
SOUTH AMERICA											
ALCALA (Association Life Cycle Analysis Latin America)	2005	X			Argentina, Brazil, Chile, Columbia, Costa Rica, Ecuador, Mexico, Peru	Yes	Yes	NA	No	No	Yes
Latin American LCA network	NA		X		Argentina, Brazil, Chile, Costa Rica, Cuba, Mexico, Peru, Spain, Portugal	Yes	Yes	NA	Yes	Yes	Yes
Argentinean LCA network				X	Argentina	Yes	NA	NA	NA	NA	NA
ABCV (Brazilian Association for Life Cycle Assessment)	2002		X		Brazil	Yes	Yes	Yes	Yes	Yes	Yes
ACV (Life Cycle Evaluation)	NA			X	Brazil	Yes	NA	NA	NA	NA	NA
Northeastern LCA Network	**2011**			**X**	**Brazil**	**Yes**	**No**	**Yes**	**Yes**	**NA**	**No**
Group of Pollution Prevention[a]	**1998**			**X**	**Brazil**	**Yes**	**NA**	**Yes**	**NA**	**Yes**	**NA**
Red ACV Chile (Chilean LCA network)	NA		X		Chile	Yes	Yes	Yes	Yes	Yes	Yes
Columbian LCA network	2010		X		Colombia	Yes	NA	Yes	Yes	Yes	Yes
Peruvian LCA network	2010		X		Peru	Yes	Yes	Yes	Yes	Yes	Yes

Table 1 (continued)

Name	Year of formation	Network identified in			Country/Countries	1: Supports a life cycle approach	2: Has members from both academia and industry	3: Is non-profit	4: Has central control and coordination	5: Is an independent entity	6: Embodies a communication platform
		Literature review	Web search	Inquiry to stakeholders							
ASIA											
ASEAN+ Network on LCA and Carbon Footprint	2008		X		Cambodia, Indonesia, Japan, Laos, Malaysia, Myanmar, the Philippines, Thailand, Vietnam	Yes	Yes	NA	Yes	Yes	Yes
SEASIA (South South-East Asia Network on Life Cycle Initiative of UNEP)	NA		X		Afghanistan, Bangladesh, Bhutan, Brunel, Brunei, Cambodia, China, East Timor, India, Indonesia, Laos, Macau, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, the Philippines, Sri Lanka, Taiwan, Tibet, Thailand, Vietnam	Yes	NA	NA	No	No	Yes
CNLCI (China Lifecycle Initiative)	NA			X	China	Yes	Yes	NA	Yes	No	Yes
Ecovane	2008			X	China	Yes	NA	No	Yes	Yes	Yes
LCI India Network	**2010**			**X**	**India**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
ISLCA (Indian Society for LCA)	**1997**	**X**			**India**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
LCA Society of Japan	1995	X			Japan	Yes	Yes	Yes	Yes	Yes	Yes
KSLCA (Korean Society of LCA)	NA	X			South Korea	Yes	NA	NA	NA	NA	Yes
LCARC (Life Cycle Assessment Research Center)	NA	X			South Korea	Yes	Yes	NA	Yes	NA	Yes
KSIE (Korea Society for Industrial Ecology)	2009			X	South Korea	Yes	Yes	Yes	Yes	Yes	Yes
Thai LCA network	2000	X			Thailand	Yes	Yes	NA	Yes	Yes	Yes
Thai National LCI Database	2000		X		Thailand	Yes	Yes	NA	Yes	No	Yes
AFRICA											
ALCANET (African LCA Network)	NA	X			Ethiopia, Mauritius, South Africa, Zimbabwe	Yes	Yes	NA	No	No	Yes
Life cycle centre in South Africa	2009			X	South Africa	Yes	Yes	Yes	Yes	Yes	No

Table 1 (continued)

Name	Year of formation	Network identified in			Country/Countries	1: Supports a life cycle approach	2: Has members from both academia and industry	3: Is non-profit	4: Has central control and coordination	5: Is an independent entity	6: Embodies a communication platform
		Literature review	Web search	Inquiry to stakeholders							
OCEANIA											
ALCAS (Australian LCA Society)	2001	X			Australia	Yes	Yes	NA	Yes	Yes	Yes
AUSLCI (Australian Life Cycle Inventory Database Initiative)	NA		X		Australia	Yes	Yes	NA	Yes	No	Yes
BP LCI (Building Products Life Cycle Inventory)	NA		X		Australia	Yes	Yes	NA	Yes	Yes	Yes
LCANZ (Life Cycle Association New Zealand)	2009		X		New Zealand	Yes	Yes	Yes	Yes	Yes	Yes
NZLCM (New Zealand Life Cycle Management center)	**2009**		**X**		**New Zealand**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Total		21[e]	37	42							

For networks without an official English name, their abbreviation (if any) was stated along with a translation of the full name. LCA networks that responded to the survey are marked in bold.

NA criteria fulfillment unknown

[a] These networks did not have the opportunity to answer our survey since they were identified by the survey response from another network (question 12b)

[b] SPOLD has evolved into focusing on the development of the EcoSpold LCI data format and has been integrated into EcoInvent (also stated as a network in our mapping). Therefore, SPOLD does not fulfill criterion 5

[c] These three institutions have all been initiated by the European Commission's Joint Research Center. They have been included as individual networks since IPTS and ELCD were suggested by stakeholders responding to our inquiry on the existence of LCA networks. ELCD has recently evolved into the International Reference Life Cycle Data System

[d] We became aware of the existence of another French network (SCORELCA, http://scorelca.org; philippe.osset@scorelca.org) shortly before submitting the paper. The network was not included in the characterization below

[e] Networks mentioned in the literature were excluded if they did not meet criterion 1

[f] The specific European countries participating in this network are unknown

to identify networks of a very diverse nature. As a result, the list of identified LCA networks provided in Table 1 is not deemed exhaustive, although the number of potentially missing LCA networks is believed to be limited. However, a number of less visible and informal networks hosted by industry associations may also exist. These remain largely unidentified since they do not necessarily share the interest of the academically rooted networks in documenting and communicating their activities to the public.

3.2 Temporal evolution

Figure 2 shows that an increasing trend in the number of new networks established each year is evident. This has so far resulted in at least seven new networks being formed each year since 2008. This trend could be the results of the recent focus on the application of LCA-related methodologies and tools initiated by the UNEP/SETAC Life Cycle Initiative's phase 2 in 2007 (UNEP/SETAC 2012).

3.3 Geographical distribution

The majority of the identified LCA networks (68) are local (country level or below). The remaining networks distribute nearly equally between regional (above country level) and global (14 and 18, respectively). A map of geographical coverage of the LCA networks is shown in Fig. 3. European countries generally score highest, with the Netherlands, Sweden, France and Spain exceeding a score of 9 (counted as the sum of local LCA networks hosted and regional LCA networks participated in). Also, parts of the Americas are well represented, and to a lesser extent Southeast Asia and Oceania. The countries obtaining the lowest scores are located in Africa, the Middle East and Central Asia. It should be noted that some countries in the European Union may be scoring high since all EU-27 member states are assumed to participate in the five European regional networks (see Table 1), although the core activities in these networks may not involve all 27 member states. The significance of the geographical distribution is explored in Section 3.5.

3.4 Network characterization

We received 25 responses to the survey,[4] corresponding to 27 % of the networks receiving an invitation. We consider this number as sufficiently high to allow a further characterization of the networks with respect to their structures and activities. We also assume these answers to be representative

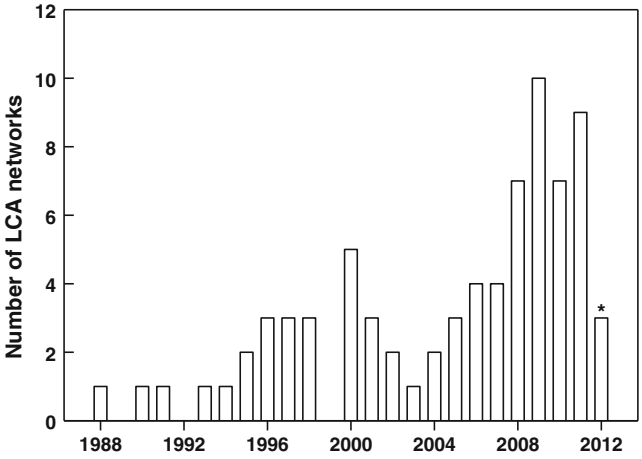

Fig. 2 Number of new networks formed every year at a global scale. For 2012, the *asterisk* indicates a partial coverage (until end of February)

of all LCA networks.[5] The full report with survey questions and answers is available in the ESM.

3.4.1 Size and funding

As Fig. 4 shows, most of the networks are small (up to 20 individual members) or medium-sized (21–100 individual members). This result matches the observation that the majority of the identified networks are local and therefore with limited potential for more than 100 members. Also, roughly half of all networks are less than 5 years old (see Fig. 2), meaning that they may not have reached a mature size yet. The networks are funded in a variety of different ways, with sole public funding or a combination of public funding and user-paid funds being the most common. Of the responders, 28 % are not funded at all, indicating that these networks must run their activities with very low costs and are based on volunteer work.

3.4.2 Composition and coverage of LCA activities

Figure 5a shows that nearly all networks have members from academic institutions, indicating that these are key elements in most LCA networks (and perhaps even a prerequisite for the establishment of a network). More than half of the responders have members from consultancies and companies of different sizes, whilst fewer have members from other institutions, such as Environmental Protection Agencies (EPAs; 12 %), standardisation organisations (20 %) and environmental NGOs

[4] The survey software reported 32 responses, but seven of them were deemed to be the result of a technical error since the answers provided were highly incomplete and incomprehensible.

[5] Twenty-five networks is not a large sample, and the survey responses may therefore be biased in one way or the other. However, since the survey answers did not indicate any bias (e.g. overrepresentation of networks covering a specific group of countries or well-funded networks), they were assumed to be representative for all the identified networks.

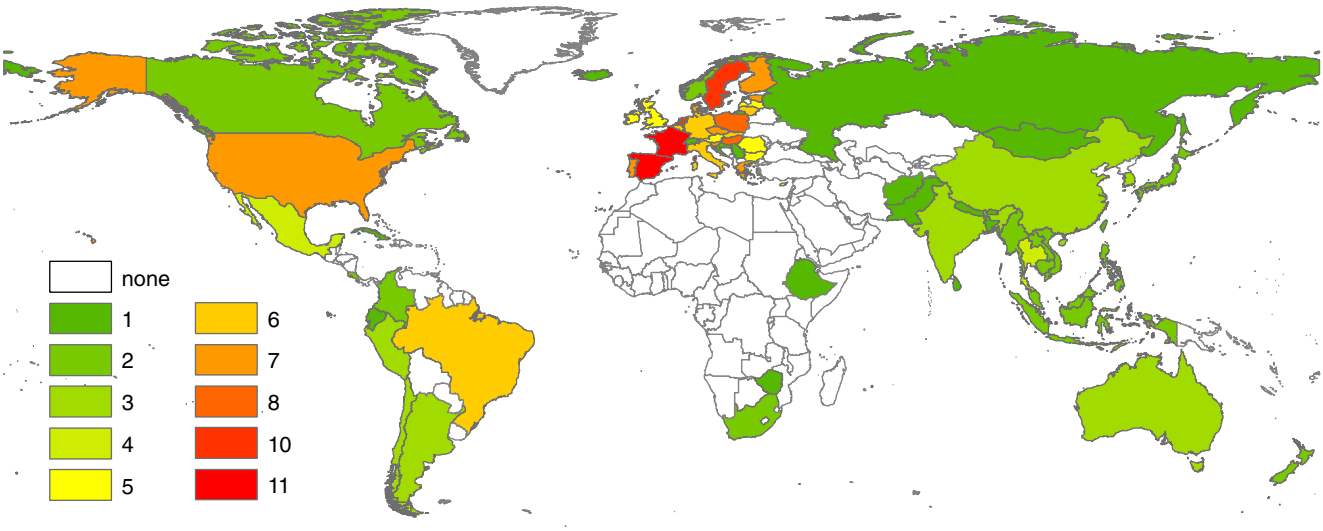

Fig. 3 Geographical distribution of LCA networks. The country score indicates the sum of local LCA networks (country level or below) and participations in regional LCA networks (above country level) per country. Global networks are excluded to make the figure more legible. East Timor and Tibet are listed as members of the South and South-East Asia (SEASIA) Network on Life Cycle Initiative of UNEP, but are not indicated in the map. For regional LCA networks covering Europe, all EU-27 member states were assumed to participate. Adapted from Bjørn et al. (2012)

(28 %). The latter indicates that LCA-related collaborations primarily happen between researchers and businesses. Networks having members from standardisation organisations and/or environmental NGOs tend to be larger than the average network. This could indicate that collaboration with these institutions may take place in a network as it grows and matures over time. However, our results do not support this since networks having one or more members from EPAs, standard organisations and environmental NGOs are on average not significantly older than the rest of the networks. Efforts may therefore be needed to further involve legislators and the general public in LCA networks.

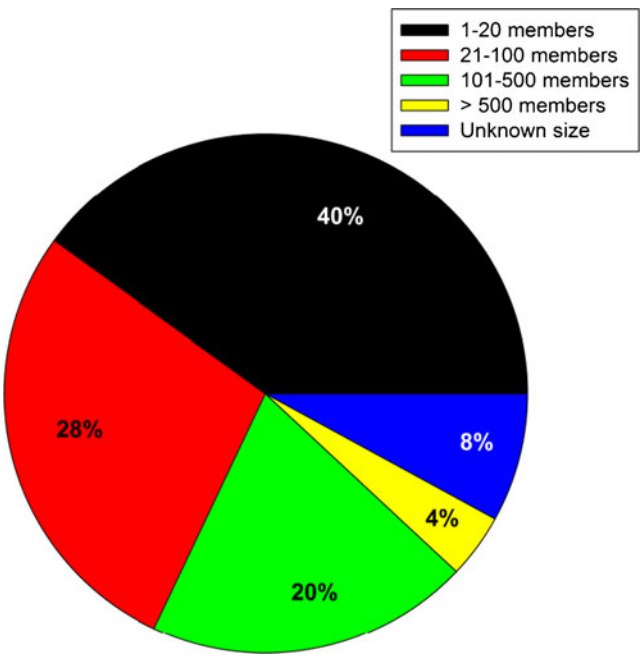

Fig. 4 Distribution of LCA networks according to size (based on survey results). '*Members*' refer to individuals

Figure 5b shows that the majority of the networks (72–84 %) work with life cycle impact assessment (LCIA), LCI, application of LCA through case studies and knowledge sharing/communication. This does not come as a surprise as these can be seen as cornerstone activities in the development and dissemination of LCA. However, emerging areas such as input/output LCA, life cycle costing and life cycle sustainability assessment (LCSA) are also taking place within 32–36 % of the responding networks, whilst only 16 % cover social LCA (which is surprising since social LCA is a core element of LSCA). This suggests that LCA networks can not only accelerate the implementation of life cycle-oriented approaches but may have the potential for becoming catalysts for the development of integrated assessment tools (such as LCSA), linking environmental, social and economic dimensions of sustainability. The emerging areas are generally less operational than the cornerstone activities, and this may explain why they were found to be underrepresented among the 28 % of the responding networks not receiving any funding.

Figure 5a shows that 52 and 56 % of the responding networks have members from small- and medium-sized enterprises (SMEs) respectively (comprising less than 50 and 50–250 employees, respectively, according to EU definition).[6] These numbers are quite high considering the fact that SMEs are known to apply LCA to a much smaller extent than larger companies. Common barriers for the application of LCA within

[6] Note that it is unknown how many members from small- and medium-sized companies each network has.

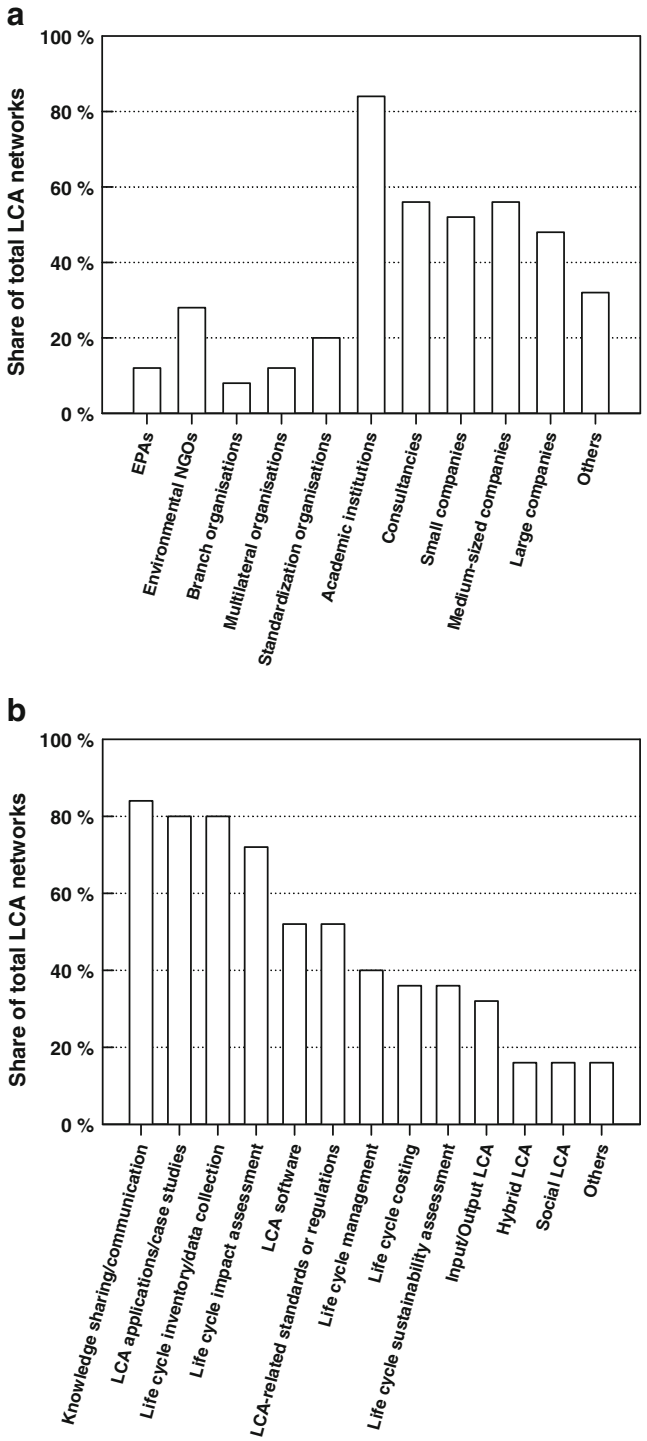

Fig. 5 **a** Types of entities represented in LCA networks (retrieved from survey results). **b** Types of activities carried out by LCA networks (retrieved from survey results)

SMEs are (1) lack of know-how, (2) resource and time-consuming, (3) limited supply chain influence and (4) high immediate costs compared to long-term benefit (Frankl and Rubik 2000; Prendeville et al. 2011). When considering the most common network activities (carried out by more than 70 % of the networks) in Fig. 5b (knowledge sharing, LCA application, LCI and LCIA), they all have the potential to help overcome especially barrier 1, but also barriers 2 and 4. This may explain why participation in LCA networks is apparently popular among SMEs despite the fact that they, to a large extent, still do not apply LCA. This apparent interest in LCA networks indicates that SMEs see a value in following the development within the field of LCA for strategic reasons so that they may, when perceived appropriate, engage in LCA activities on their own.

3.4.3 Dissemination activities and communication

The majority of the networks communicate through web site and hosting of conferences, whereas hosting of online courses or seminars and publishing newsletters are less common (32–36 % of responders). Most responding networks use their web site to create awareness, in addition to utilizing their contact to academia and industry. Also, 72 % of the responders are in communication and/or cooperation with other networks. This indicates that networks naturally have a high degree of communication with each other and different LCA-related organisations.

3.4.4 Networks in developing economies

Six networks from developing economies responded to the survey. Their answers were analysed for clear differences in characteristics compared to networks situated in developed economies. Fewer networks in developing economies were found to work with LCA software and communicate through a web site (33 and 50 %, respectively) than in developing economies (63 and 84 %, respectively). This might be explained by a relatively high cost of hardware, software and training experienced by networks in developing economies for such activities. More networks in developing economies are hosting conferences and creating awareness of their networks through open seminars (100 and 67 %, respectively) than in developed economies (42 and 16 %, respectively). Similarly, more networks in developing economies (67 %) create awareness of their network through contact with authorities than in developed economies (37 %). Interestingly, 67 % of the networks in developing economy have members from environmental NGOs compared to only 21 % of the networks in developed countries. These results indicate that both structure and activities of LCA networks are region-specific, which may reflect that priorities related to the development and dissemination of LCA are also region-specific.

3.4.5 Network characteristics in relation to criteria fulfillment

To investigate whether the characteristics of networks vary with to the networks' criterion fulfillment, all networks were grouped

Table 2 Grouping of LCA networks

Group no.	Criteria fulfillment						No. of networks in group	No. of survey answers
	1: Supports a life cycle approach	2: Members from both academia and industry	3: Is non-profit	4: Central control and coordination	5: Is an independent entity	6: Embodies a communication platform		
1	Yes	Yes	Yes	Yes	Yes	Yes	29–58	16
2	Yes	No	Yes	Yes	Yes	Yes	10–14	3
3	Yes	Yes	No	Yes	Yes	Yes	5–21	2
Total number of criteria fulfillments: yes; no; unknown	100; 0; 0	66; 17; 17	47; 6; 47	88; 6; 6	75; 16; 9	89; 6; 5		

Only groups containing five or more networks (lower limit) have been included. It was not always possible to establish whether or not the networks fulfilled the individual criteria. Thus, of the 600 criteria to be checked (100 networks × 6 criteria per network) a 'yes' or 'no' could not be determined for 83 criteria, corresponding to 14 % of all criteria to be checked. To account for this uncertainty, two groupings were done. In the first, all unknown criteria fulfillments were replaced by yes and in the second all were replaced by no. This explains the interval surrounding the number of networks per group

according to their fulfillment of the six criteria. Subsequently, it is possible to analyse the survey response of each group, presented in Table 2, and investigate possible trends.

The largest group is composed of 29–58 networks that fulfill all criteria, whereas the second and third largest groups represent networks that fulfill all criteria, but criterion 2 ('Members from both academia and industry') and criterion 3 ('Is non-profit'), respectively. The fact that only three groups containing five or more networks were identified is an indication that the networks show a high degree of variation in terms of their criterion fulfillment.

The only group with a sufficient number of survey responses to enable interpretation of trends is group 1 (fully qualifying networks). One trend is that EPAs and NGOs participate in a larger share of fully qualifying networks than in partly qualifying networks. This could indicate that fully qualifying networks, to a larger degree than others, are promoting LCA activities to legislators and the general public. With respect to coverage of LCA activities, the only clear trend observed was (counterintuitively) that a smaller share of fully qualifying networks (13 %) deals with LCSA than that of partly qualifying networks (78 %). There is also a trend of fully qualifying networks to carry out more communication activities than partly qualifying ones. This is especially evident regarding conference hosting, which is carried out by 75 % of the fully qualifying networks, but only 22 % of the partly qualifying ones. Finally, 63 % of the fully qualifying networks considered themselves networks, whereas that figure is 44 % for partly qualifying networks. These low numbers may indicate that our definition is too broad and that the criteria could be refined. However, a rigid network definition fitted poorly in the context of this study since networks of different characters could all be relevant to include, when the purpose was to map (ideally) all networks that may contribute to the scientific development of LCA and the dissemination of developed tools and methods. In future studies with similar scopes, it is therefore not recommended to rigidly define a large number of absolute criteria, but rather to define a few absolute criteria and apply a number of other criteria as a mean of grouping identified networks. [7]

3.5 Potential roles and outcomes of LCA networks in the development of LCA

It would be interesting to know to what extent the activities of LCA networks help disseminate life cycle approaches among industries and authorities in the regions they cover. However, evaluating whether this is an actual outcome of the networks' activities is not easy (mainly because it is difficult to quantify the difference relative to a hypothetical reference situation where the networks do not exist). A tentative measure of the impact of networks may be created comparing their development to the development in scientific production (which may or may not have been catalyzed by LCA networks) within the region that they cover. Figure 6 shows that the temporal evolution of LCA networks and LCA publications (only covering those indexed in the ISI Web of Science) has experienced a rapid, seemingly correlated increase since the first LCA network and publications appeared in 1988 and 1993, respectively.

[7] Besides criterion 1, a variation of criterion 2 is recommended as an absolute criterion since some sort of cooperation between academia and other institutions is deemed crucial for the dissemination and feedback of LCA methods and tools. Criteria with a high number of unknown's (see last row of Table 2) should be replaced by criteria, which are easier to test (ideally through the network web pages). Also, criteria showing a high degree of covariation (such as criteria 4 and 6) could be merged to simplify future mappings.

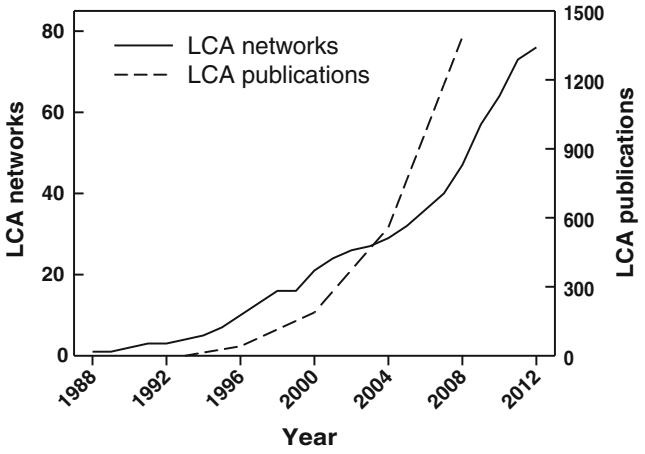

Fig. 6 Time series for (1) aggregated number of established networks globally (it was only possible to identify the year of formation for 76 of the 100 identified networks. For 2012, the graph only covers until the end of February) and (2) aggregated number of LCA publications globally as indexed in the Web of Science database (de Souza and Barbastefano 2011). Articles published prior to 1993 have not been included in the figure due to lack of data

It would appear that LCA networks predate LCA publications, but a closer inspection reveals that networks exclusively dedicated to LCA (i.e. 'LCA' being part of their name) were not formed until 1995. Older networks dealing more broadly with environmental and sustainability issues are likely to have adopted LCA activities some time after their establishment. After the year 2000, the growth in publications exceeded that of network formations, suggesting that LCA networks may have a catalytic effect on the scientific output in the form of publications. A possible explanation is that networks facilitate contact between researchers from different institutions and industry representatives (as was found in Section 2.4.2) who may provide cases to test LCA methodologies as well as provide feedback to academia on the operationalization of the latest methodological development. Similar trends were observed at continental scales (ESM Fig. S1), indicating that the global trend in Fig. 6 does not hide large regional variations.

Figure 7a shows that a significant correlation between the number of networks and the number of LCA publications is observed at a scale of continents. On the contrary, no apparent trends between the number of LCA networks and the number of LCA-related articles are observed at the country level (see Fig. 7b), where some countries have a high publications/LCA networks ratio (such as USA and Japan) and some countries have a low ratio (such as Ireland and Brazil). This may suggest that the LCA network activities on a country basis are not decisive for the number of publications that are produced by researchers in that country. Instead, LCA researchers seem to be international in the cooperation on research and scientific publication, although they are seemingly largely restricted to a

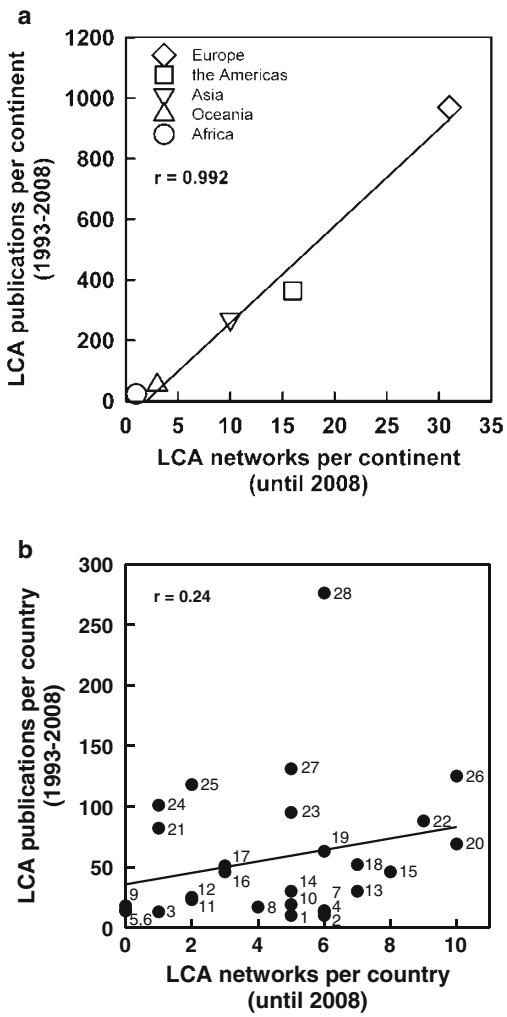

Fig. 7 **a** Relation between number of LCA networks per continent (local or regional) and number of LCA publications in each continent as indexed in the Web of Science database (data from de Souza and Barbastefano 2011). Publications may be double counted if authors represent more than one continent. Networks with no information on formation year were assumed to have been formed before 2009. *Solid line* shows a linear regression fit to the data. r=Pearson correlation coefficient; the correlation is statistically significant at $P<0.05$. Updated from Bjørn et al. 2012. **b** Relation between the number of LCA network per country (sum of local networks hosted and participation in regional networks) and the number of LCA publications in 20 countries as indexed in the Web of Science database (data from de Souza and Barbastefano 2011). Publications may be double counted if authors represent more than one country. Networks with no information on formation year were assumed to have been formed before 2009. Only countries with at least ten publications have been included. *Solid line* shows a linear regression fit to the data. r=Pearson correlation coefficient; the correlation is not statistically significant at $P<0.05$. Numbers correspond to: (*1*) Ireland, (*2*) Brazil, (*3*) Taiwan, (*4*) Portugal, (*5*) Singapore, (*6*) Scotland, (*7*) Greece, (*8*) Thailand, (*9*) South Africa, (*10*) Austria, (*11*) South Korea, (*12*) Norway, (*13*) Finland, (*14*) Belgium, (*15*) France, (*16*) Australia, (*17*) China, (*18*) Denmark, (*19*) Italy, (*20*) Spain, (*21*) Canada, (*22*) the Netherlands, (*23*) England, (*24*) Switzerland, (*25*) Japan, (*26*) Sweden, (*27*) Germany, (*28*) USA

continental scale (see Fig. 7a). This conclusion may be supported by de Souza and Barbastefano (2011) who noted that the number of multi-authored LCA-related publications had grown far more (1:11) than single-authored ones (1:2) between the periods 1993–1996 and 2005–2008 (assuming that the growth in multi-authored articles is at least partly due to a growth in international cooperation on publications). Another explanation of the missing trend on a country basis (7b) could be the variance of size and priorities of networks (see also Section 3.4.4). Large, research-focused networks may be more present in some countries than in others, thus resulting in the observed scattered picture. More detailed information on each network would be required to unveil the mechanisms behind these observations.

A final remark on the possible correlations presented in this section is that the causal relations between the investigated parameters are not known. Our results indicate that LCA networks may facilitate and catalyze scientific output in the form of publications (e.g. authors being affiliated with LCA networks). However, since this link has not been investigated in detail, it is also possible (although less intuitive) that scientific output, or other forms of LCA dissemination, drives the establishment of LCA networks or that there is no causal relationship between the observed development of the two parameters, whereas they are both the consequence of a deeper trend in society such as the increased focus on corporate sustainability and the need for a life cycle perspective to assess this.

4 Conclusions and perspectives

Using our criteria-based definition of an LCA network, we mapped 100 local, regional and global LCA networks from around the world. The provided list is the most comprehensive, publicly available mapping. More research is, however, needed to investigate the potential roles LCA networks may play in facilitating the dissemination and application of LCA tools and the development of methodologies.

Our results may serve as a starting point for deciding how the dissemination and development of LCA are increased most effectively worldwide. We suggest that the networks identified in this study could provide an initial basis for the establishment of an online database, where unidentified and newly established networks will have the opportunity to register themselves. In carrying out this study, it was realized that LCA networks vary greatly in terms of structure, size, activities, etc. An online database should acknowledge this and allow for networks to be grouped according to their characteristics to create a better overview for networks seeking knowledge on other networks as well as individuals seeking inspiration to establish a network. A supplementary initiative that could facilitate communication between networks and individuals would be the establishment of a web-based platform dedicated to knowledge and experience sharing.

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